A Climate Modelling Primer

Building an EBM with Excel

1. Introduction

This document tells you how to build an EBM using a common spreadsheet. The example uses Excel 5.0, but ought to be readily adaptable to most commonly available programs. If you don't have a spreadsheet, you ought to be able to use this guide to get the EBM coded up in whatever programming language you have available. To get a fuller understanding of where the equations come from, you'll need a copy of the book handy.

2. The model domain

The model we will build is a hemispheric model and we will divide the hemisphere into 10 latitude bands placed in column B (Figure 1).

Zones
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10

Figure 1

We add another column which gives the central latitude of each band. We will consider this latitude as representative of the band. We also need to say how the solar radiation is distributed (SunWt column in Figure 2). Note that we don't use a simple cosine function. That would give zero at the poles. We need to use a distribution which takes into account the tilt of the Earth's axis. These weights will be applied to the 1370/4 figure which comes from the basic geometry of the situation.

Zones		SunWt
80-90	85	0.5
70-80	75	0.531
60-70	65	0.624
50-60	55	0.77
40-50	45	0.892
30-40	35	1.021
20-30	25	1.12
10-20	15	1.189
0-10	6	1.219

Figure 2

Now we add some formatting and also the fixed parameters of the model. The definitions of the parameters in the boxes should be clear from the book (Chapter 3). The albedo (Init_a column) is a function of temperature (Init_T), so we need to "fill-down" the column of albedos with the formula shown. The first one comes out as 0.6 since the temperature is -15 (Figure 3).

Figure 3

Next we need to look at the radiative input and output; but first we'll set up a location where our final results will be. We'll want to know what the final albedo is as well as the temperature and the radiation balance (Figure 4).
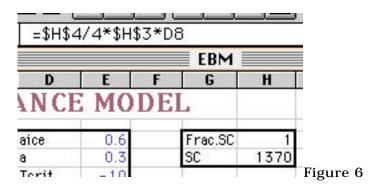

Figure 4

The next step involves us performing iterations on the temperature distribution as discussed in Chapter 3. We need a mean temperature for the hemisphere, which we'll use for the 'transport' term and we also need a radiation balance at each stage. We'll make 50 iterations each time, since there isn't a way to implement a convergence criterion in a spreadsheet. Non-convergence after 50 iterations means that the temperature is probably heading to absolute zero.

Here is the first iteration box (Figure 5).

Figure 5

Note the Tcos column, which we'll need when working out the global mean temperature. We need to area-weight the temperatures since the temperatures at the pole are for a much smaller area. We need the Rin column to be filled in at this stage. Rin is the top-of-the-atmosphere input radiation, which doesn't change, so we can fill this in in the 'final' section. The formula is shown in Figure 6.

Figure 6

The formula for the 85°N input radiation is then S/4 multiplied by the solar weighting value in column D. Check your spreadsheet manual if you don't follow the meaning of the $ symbols.

The formula for the calculation of the temperature in Step_2 (the general case) is

=($I8*(1-O8)+$C$5*Q$17-$C$3)/($C$4+$C$5)

This is copied straight from the book (Chapter 3)

Tcos is given by

=N8*$L8

and the albedo by

=IF(Q8<$E$5,$E$3,$E$4)

The first two steps are the hardest to set up. Step one refers back to the initial conditions which we set up early on(way over to the left) and step two is made up of the generalized formulae. They refer to step one and can be copied in blocks of three (marked in Figure 7) to form as many iterations as are needed. How you accomplish this will depend on your spreadsheet. Excel 5.0 allows you to fill blocks out with the mouse. Note that the mean temp at each step is based on the temperatures at the previous step and that the albedo for each step is calculated based on the temperature at that step (ready for the next step).

	Step_1			Step_2		
			>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>			
	Temp	Albedo	Tcos	Temp	Albedo	cos
31	-13.9	0.6	-1.2124	-13.546	0.6	-1.
88	-13.2	0.6	-3.417	-12.843	0.6	-3.
11	-0.48	0.3	-0.2011	-0.1183	0.3	-0.
68	5.319	0.3	3.0512	5.67694	0.3	3.2
71	10.16	0.3	7.1858	10.5196	0.3	7.4
29	15.28	0.3	12.5189	15.6401	0.3	12.
31	19.21	0.3	17.4123	19.5697	0.3	17.
25	21.95	0.3	21.2031	22.3086	0.3	21.
87	23.14	0.3	23.0151	23.4994	0.3	23.
_T	13.31			13.8711		

Figure 7

The block of three columns outlined above can then be copied as often as is needed (max 50).

The last thing we need to do is to copy the final temperature and albedo distribution from the far right of our workspace. In this example, the global mean temperature is copied too. We could also add a convergence indicator if

desired. The final model sheet should look like the one in Figure 8. Since we put all the working over to the right, we don't need to go back to it.

Figure 8

The model could be expanded by extending the columns downwards. Graphs could be added and more sophisticated albedo parameterizations tested. The sample used here is included on the CD, but you should build your own. The file on the CD was saved in Excel 3.0 format for maximum compatibility.